

Osseous Tissue & Skeletal Structures

Primary Functions of Skeletal System

1. **support**
2. **storage of minerals & lipids**
 - calcium salts provide vital minerals
 - lipids are in stored yellow marrow
3. **blood cell production**
 - RBC's, WBC's, and other constituents produced
4. **protection**
 - ribs: heart & lungs
 - vertebrae: spinal chord
 - skull: brain
 - etc.
5. **leverage:** w/o bone contracting muscles just get short & fat

Classification of Bones

- Every adult skeleton contains 206 bones which can be arranged into six broad categories according to shape

1. Long bones (relatively long and slender)

- Found in arm, forearm, leg, palm, soles, fingers, toes
- The femur is the largest and heaviest bone in the body

2. Short Bones (box-like)

- Carpal bones in wrist, tarsal bones in ankle

3. Flat bones (thin roughly parallel surfaces)

- Roof of skull, ribs, the sternum, scapula
- Provide great protection
- Provide lots of surface area for muscle attachment

4. Irregular bones (complex shapes with short, flat, notched or ridged surfaces)

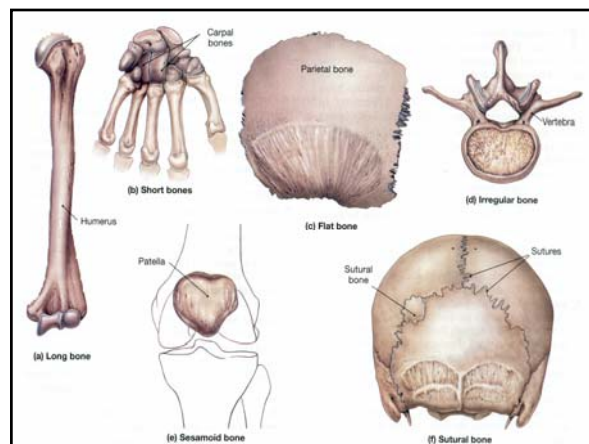
- Spinal vertebrae and several skull bones

5. Sesamoid bones (generally small, flat, and shaped like sesame seed)

- Develop inside tendons, commonly near joints
- i.e.- the patellae

6. Sutural bones (wormian bones)

- Small, flat, irregularly shaped bones, form between flat bones of skull



Each bone contains two types of Osseous (bone) tissue

1. Compact (dense) tissue:

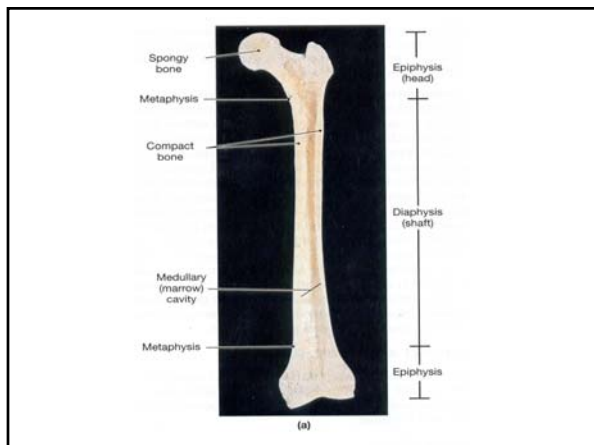
- Tightly packed
- Occurs on outside surface of bone for strength & protection

2. Spongy tissue:

- Open network of struts and plates
- Found in interior of the bone

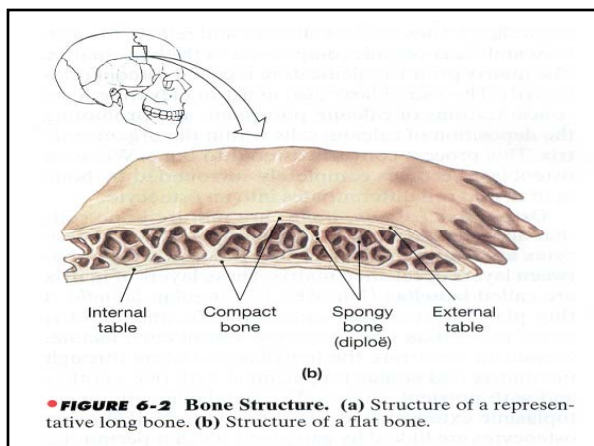
Long bones

- Spaces in the joints are filled with synovial fluid
- The epiphysis in the joint is covered by a layer of hyaline cartilage called articular cartilage.
- The medullary cavity and the open spaces of the epiphysis are filled with marrow:
 - a. **yellow marrow**: dominated by fat cells
 - b. **red marrow**: immature red, white, and blood stem cells



Flat bones

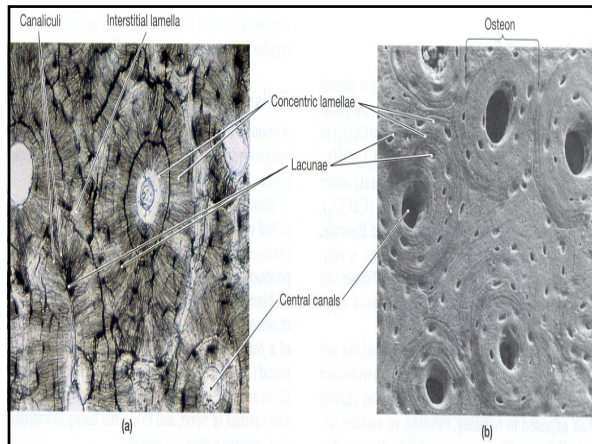
- diploë contains marrow, but there is no medullary cavity
- diploë is sandwiched between the internal and external table



Bone Histology

Basic features of Bone organization:

1. **matrix**: very dense contains deposits of calcium salts
2. **lacunae**: pockets in the matrix which contain osteocytes (bone cells)
3. **canaliculi**: narrow passageways between lacunae
4. **periosteum**: covering of bone, fibrous outer layer, cellular inner layer



Matrix of bone

≈ 2/3 of bone $\text{Ca}_3(\text{PO}_4)_2$

≈ 1/3 of bone is collagen fibers

The rest: other Ca salts (like hydroxyapatite), ions, osteocytes and other cell types

- $\text{Ca}_3(\text{PO}_4)_2$ crystals are hard but brittle
- They can withstand compression but will shatter when bent or twisted
- Collagen fibers are very strong and flexible
- Resist tension, bending, or twisting but are no good for compression

So..... hydroxyapatite crystals are tightly bound to collagen fibers giving the bone a mineral-protein composite with properties intermediate to both

•Bones end up being very tough, shatter resistant, and strong. They seem to have the strength characteristics of steel reinforced concrete.

Cells in bone

There are 4 different bone cell types:

1. **osteoprogenitor cells:** stem cells which divide to produce daughter cells which will become osteoblasts. These are important in repairing new bone
2. **osteoblasts:** responsible for formation of new bone matrix (osteogenesis)

3. **osteocytes:** mature bone cells, account for most of the bone cell population

two main functions:

- a. recycle calcium salts in the matrix around them
- b. participate in the repair of damaged bone around them

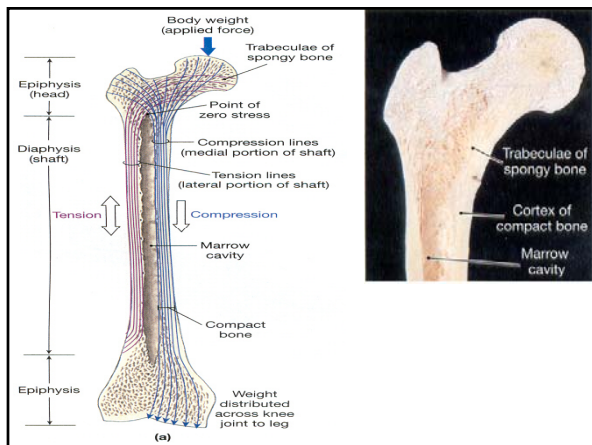
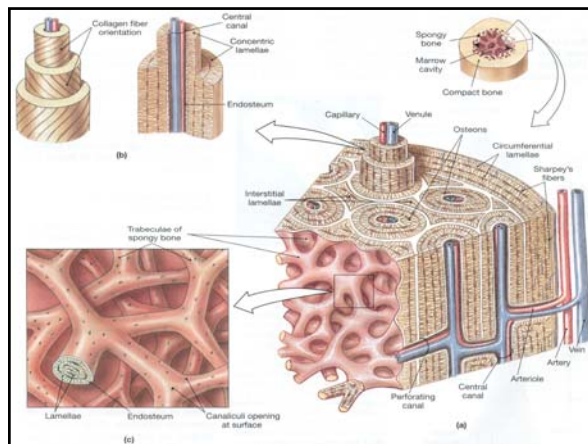
4. **osteoclasts:** giant cells, 50 or more nuclei. These dissolve bone matrix in a process called osteolysis releasing minerals

Compact Bone

- Basic functional unit is the **osteon** (Haversian system)
- Osteocytes are arranged around a central canal (generally run parallel to surface)
- Normally this cavity contains a capillary and a venule
- Other small perforating canals (Volkmann's canals) run perpendicular to the surface
- Built to withstand stress and shear force

Spongy bone (cancellous bone)

- No osteon or blood vessels
- The struts and plates of the cancellous part are called **trabeculae**
- Spongy bone is located at areas of low stress, or where stress arrives from many directions
- Much lighter than compact bone
- The trabeculae protect the precious red marrow



Periosteum / Endosteum

•All bones (except joints) are covered by a membrane called the periosteum {fibrous outer layer, cellular inner layer}

The **periosteum** has three main functions:

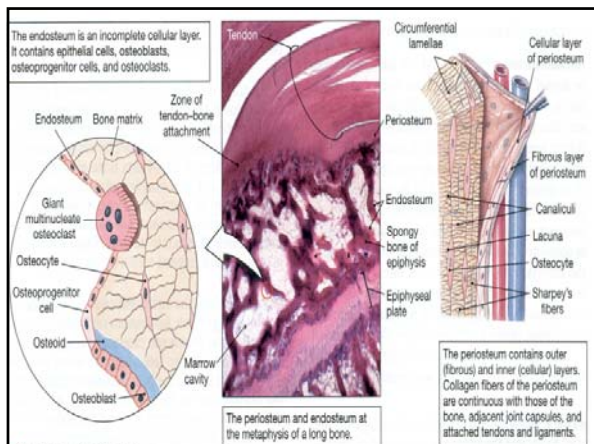
1. isolate bone from surrounding tissue
2. provides route for circulatory and nervous supply
3. actively participate in bone growth & repair

- At joints the periosteum becomes continuous with the articular cartilage, and tendons/ligaments at sites of muscle attachment
- This provides for a VERY STRONG joint.
- A good pull on a joint will usually break a bone before ripping these collagen fibers

A cellular layer called the **endosteum** covers or lines the following surfaces:

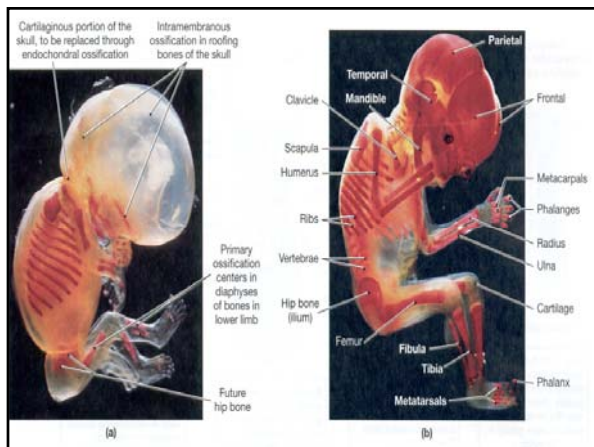
- Medullary cavity
- Central canals
- Trabeculae

*the endosteum is active in bone growth, repair and remodeling



Bone Growth & Development

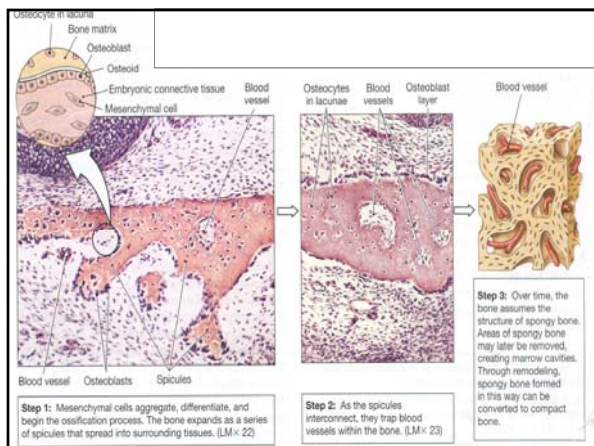
- Growth of the skeleton determines the size and proportions of our bodies
- The skeleton begins to form ≈ 6 weeks after fertilization (embryo is only 12 mm long)
- Bone growth continues through adolescence with some bone continuing to grow through age 25
- Fetal skeletons are cartilaginous. They eventually turn to bone in a process called ossification



There are two types of ossification

1. intramembranous ossification

- bone develops from mesenchyme or fibrous connective tissue.
- Step 1:** mesenchymal cells at the ossification center secrete matrix materials (which crystalizes) and differentiate into osteoblasts
- Step 2:** developing bone grows outward from the ossification center
- Step 3:** remodeling produces spongy & compact bone



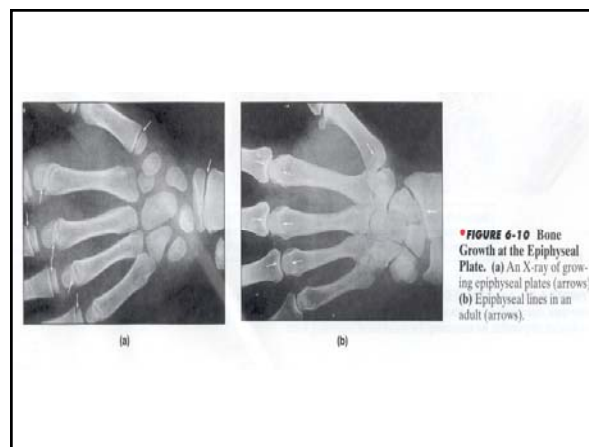
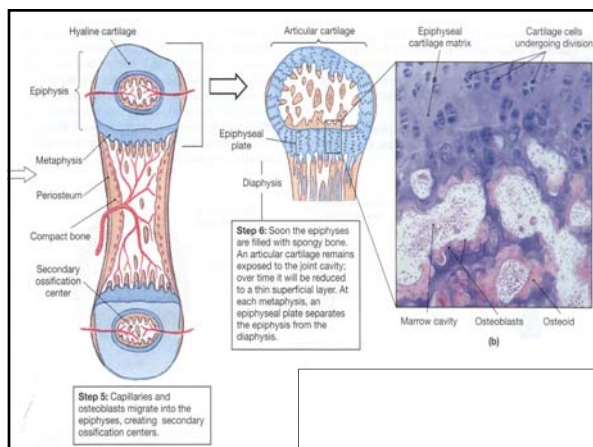
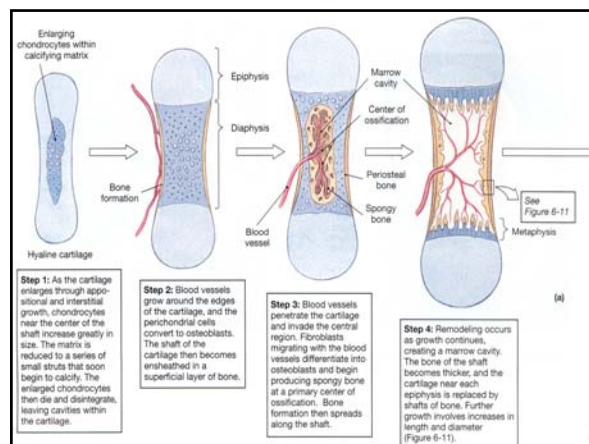
2. endochondral ossification

- *most bone is made this way
 - *bone replaces existing cartilage
- Step 1:** cartilage enlarges, calcifies and dies
- Step 2:** blood vessels grow into perichondrium
- Step 3:** calcified cartilaginous matrix breaks down and the fibroblasts present differentiate into osteoblasts at the primary center of ossification

Step 4: bone enlarges, medullary cavity is formed, bone increases in length and diameter

Step 5: center of epiphysis begin to calcify, secondary ossification centers arise at the ends of major long bones

Step 6: epiphyses filled with spongy bone and covered with hyaline cartilage



The Blood and Nerve Supply

- Bones of the skeleton typically have an extensive blood supply

3 major sets of blood vessels develop

1. The nutrient artery and vein:

- Supply the diaphysis / enter through one or more foramina

2. Metaphyseal vessels:

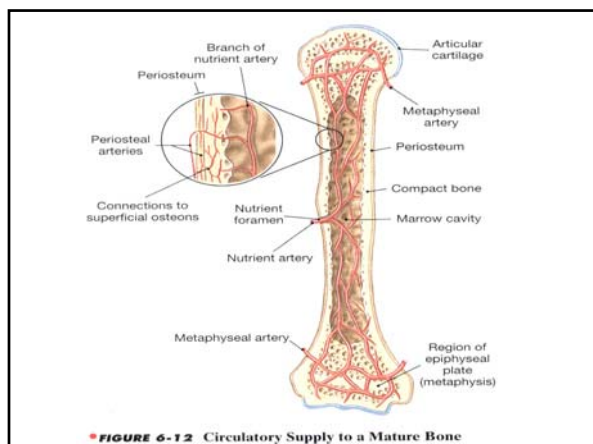
- Supply blood to the epiphyseal plate where bone growth is most rapid

3. Periosteal vessels:

- Supply surface cells of bone, develop in from periosteum

*Eventually, as the bone hardens all three of these supplies interconnect

- Sensory nerves enter with the nutrient artery and form a large nerve network. Injuries to bone tend to be very painful



Bone is a very Dynamic Tissue

- As part of a bone maintenance program, your bones are being broken and “reproduced” throughout life
- Involves a series of metabolic activities between osteoblasts, osteoclasts, and osteocytes
- Generally the activity between these cell types is balanced. As one osteon is produced, one is destroyed, etc.
- Turnover rate is high. In young adults 1/5 of skeleton is replaced each year

There are regional differences

- Spongy bone in head of femur is replaced 2-3 times/year
- The compact bone in the diaphysis remains largely unchanged

Effects of exercise on bones

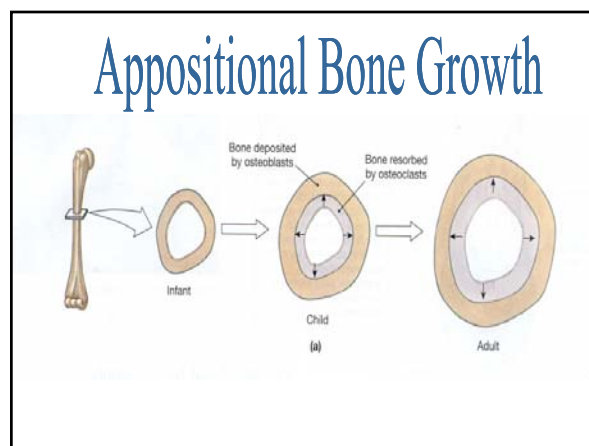
- Bones adapt to new stresses

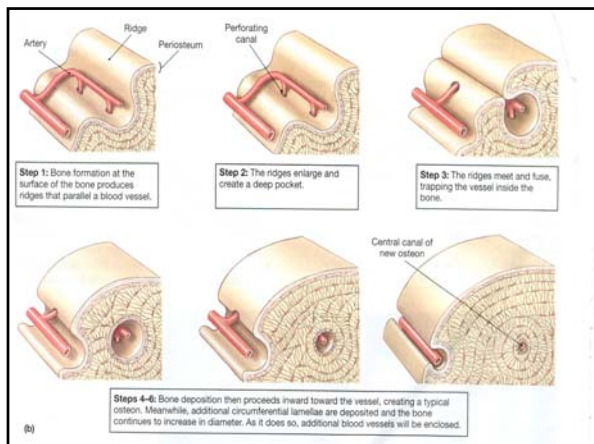
Theory for mechanism

- Stressing bone generates minute electric fields around mineral crystals
- Osteoblasts are apparently attracted to the electric field
- Once in the area they begin to produce bone
- Electrical fields are also used to stimulate the repair of bones in severe fractures

Because bones are adaptable they reflect the forces and stresses applied to them

- Heavily stressed bones become thicker and stronger
- Bones subject to ordinary stress become thin and brittle





Normal bone growth depends on nutritional and hormonal factors

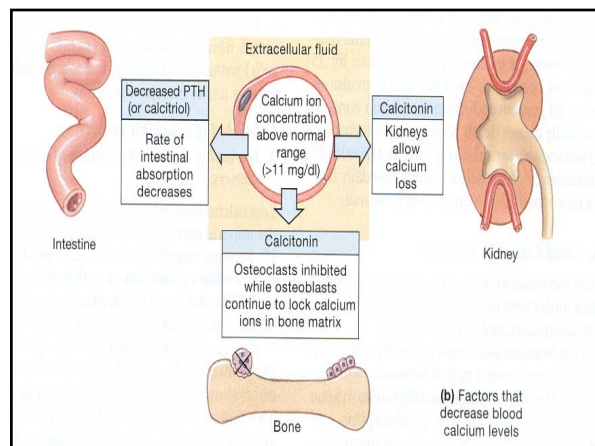
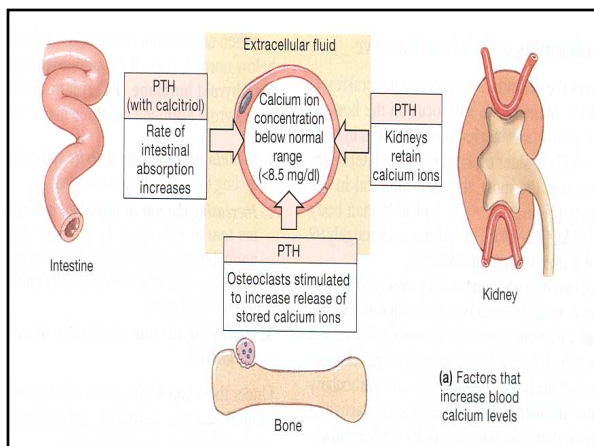
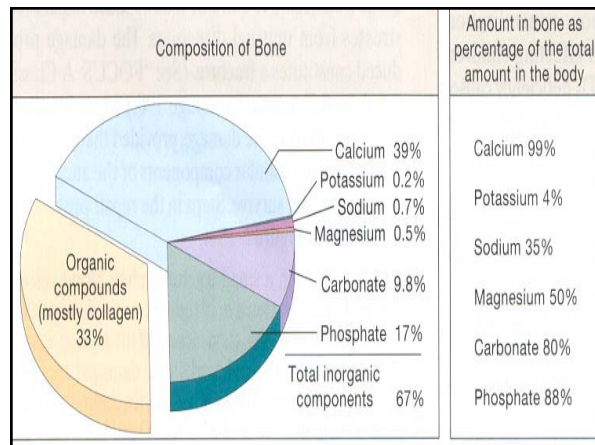
1. The body must have a constant supply of dietary calcium and potassium salts. Also required in trace amounts are: Mg, Fe, Fluoride, and Mn
2. Calcitriol is a hormone produced in the kidneys and is essential for normal Ca^{+2} & K^{+} ion absorption in the digestive tract.
3. Vitamin C must be available in the diet
4. Vitamin A, K, & B_{12} also have a significant effect on bone development

5. Growth Hormone from the pituitary gland & Thyroxin from the thyroid gland stimulate bone growth

6. Sex hormones estrogen and androgen stimulate bone growth

7. parathyroid hormone: \uparrow calcium ion conc. In body fluids

8. calcitonin: \downarrow calcium ion conc. In body fluids



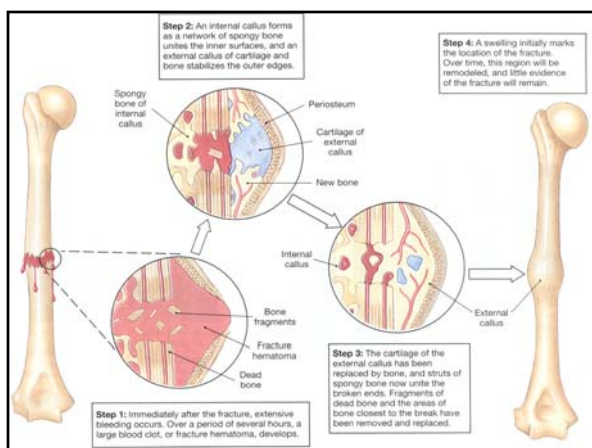
Fracture Repair

•Most bone fracture or breaks will repair (even after severe damage) if the blood supply is not interrupted



Steps to Repair

1. Blood vessels break in area causing extensive bleeding. This is eventually stopped by a big clot called a Fracture Hematoma
2. Cells near the fracture divide and differentiate into bone producing cells. An external callus forms around the outside of the fracture and an internal callus forms around the medullary cavity on the inside of the bone.
3. External & Internal calluses form structurally strong spongy bone
4. Over 4 months to a year the spongy bone is converted to compact bone



Osteoporosis



• **FIGURE 6-16** The Effects of Osteoporosis. (a) Normal spongy bone from the epiphysis of a young adult. (SEM x 23) (b) Spongy bone from a person with osteoporosis. (SEM x 19)

An Introduction to Skeletal Terminology

General Description	Anatomical Term	Definition
Elevations and projections (general)	Process	Any projection or bump
	Ramus	An extension of a bone making an angle to the rest of the structure
Processes formed where tendons or ligaments attach	Trochanter	A large, rough projection
	Tuberosity	A smaller, rough projection
	Tubercle	A small, rounded projection
	Crest	A prominent ridge
	Line	A low ridge
Processes formed for articulation with adjacent bones	Head	The expanded articular end of an epiphysis, separated from the shaft by the neck
	Neck	A narrow connection between the epiphysis and diaphysis
	Condyle	A smooth, rounded articular process
	Trochlea	A smooth, grooved articular process shaped like a pulley
	Facet	A small, flat articular surface
	Spine	A pointed process
Depressions	Fossa	A shallow depression
	Sulcus	A narrow groove
Openings	Foramen	A rounded passageway for blood vessels and/or nerves
	Fissure	An elongate cleft
	Sinus or antrum	A chamber within a bone, normally filled with air

